Multi-Angle Imager for Aerosols (MAIA) Thermal Control System

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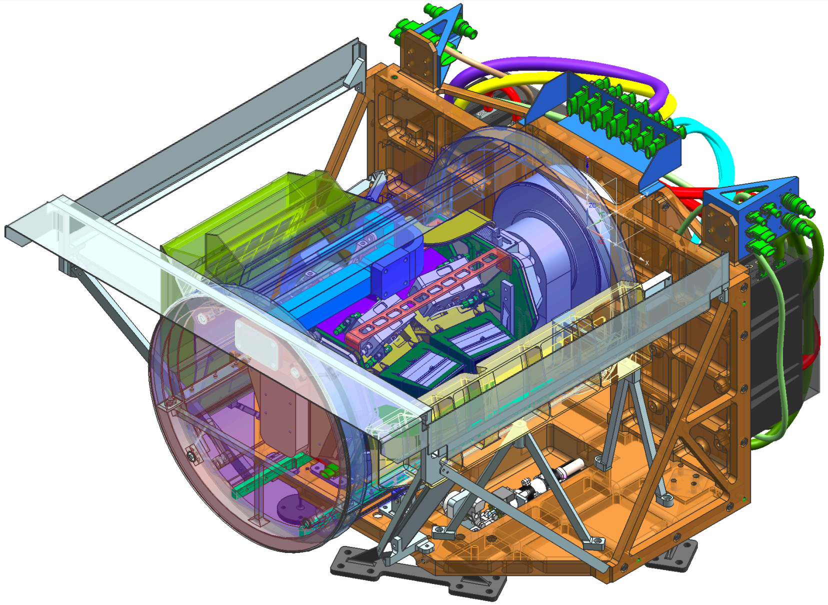
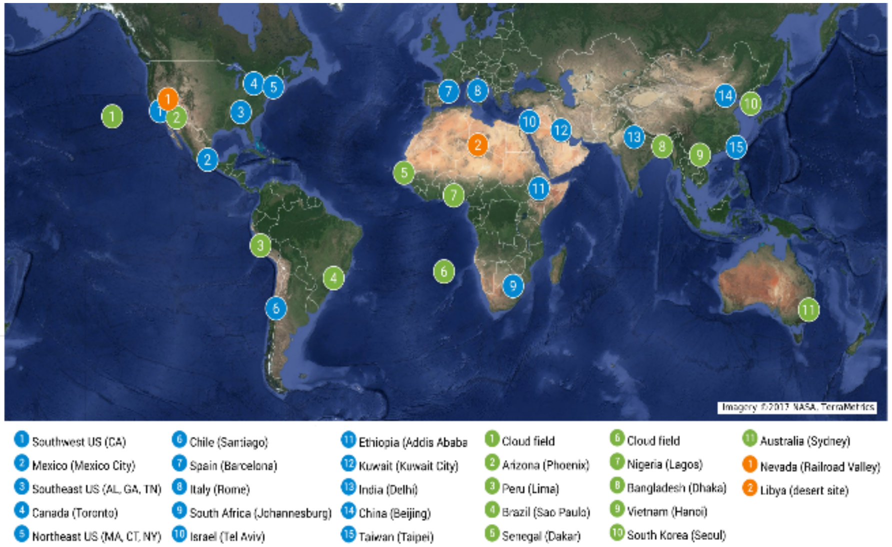
Background (1 of 3)

MAIA is a NASA-funded instrument that will help characterize airborne particulate matter within a number of population centers across the globe using multi-angle spectropolarimetric imagery

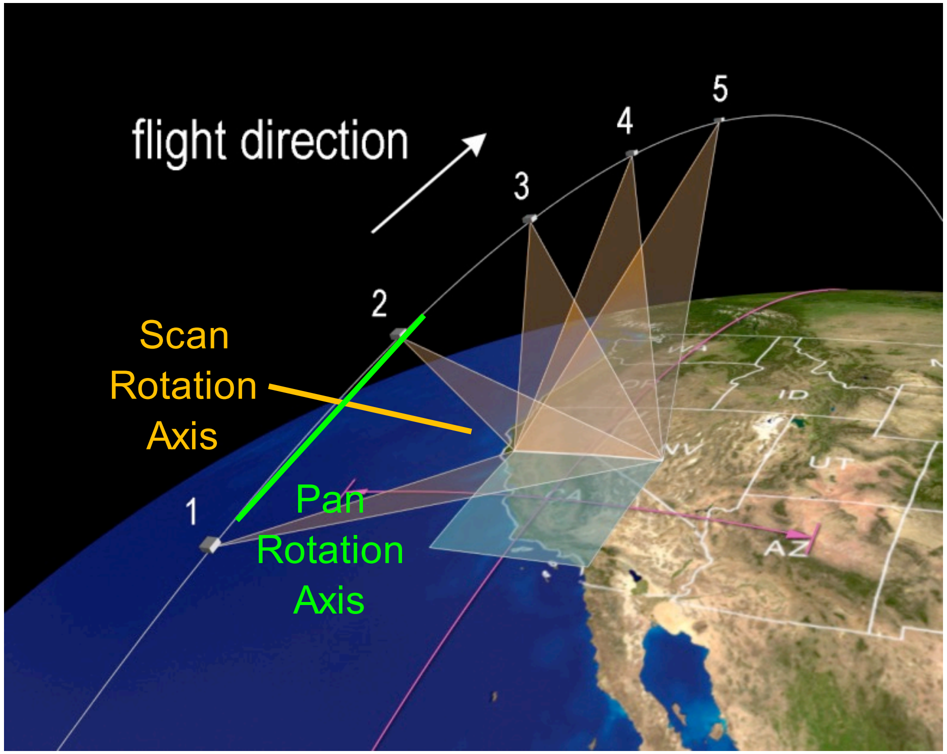




MAIA's objectives include the assessment of impacts of different size and compositional mixtures of airborne particulate matter on adverse health outcomes

Background (2 of 3)

- LEO sun-synchronous orbit
- ≈ 98° Inclination
- 9:00 am to 3:00 pm equator crossing
- 11:30 am to 12:30 pm stay out zone
- ≈1° to ≈ 50° beta range
- 600km - 850km altitude
- Two axis pointing
  - Scan, along track
  - Pan, across track

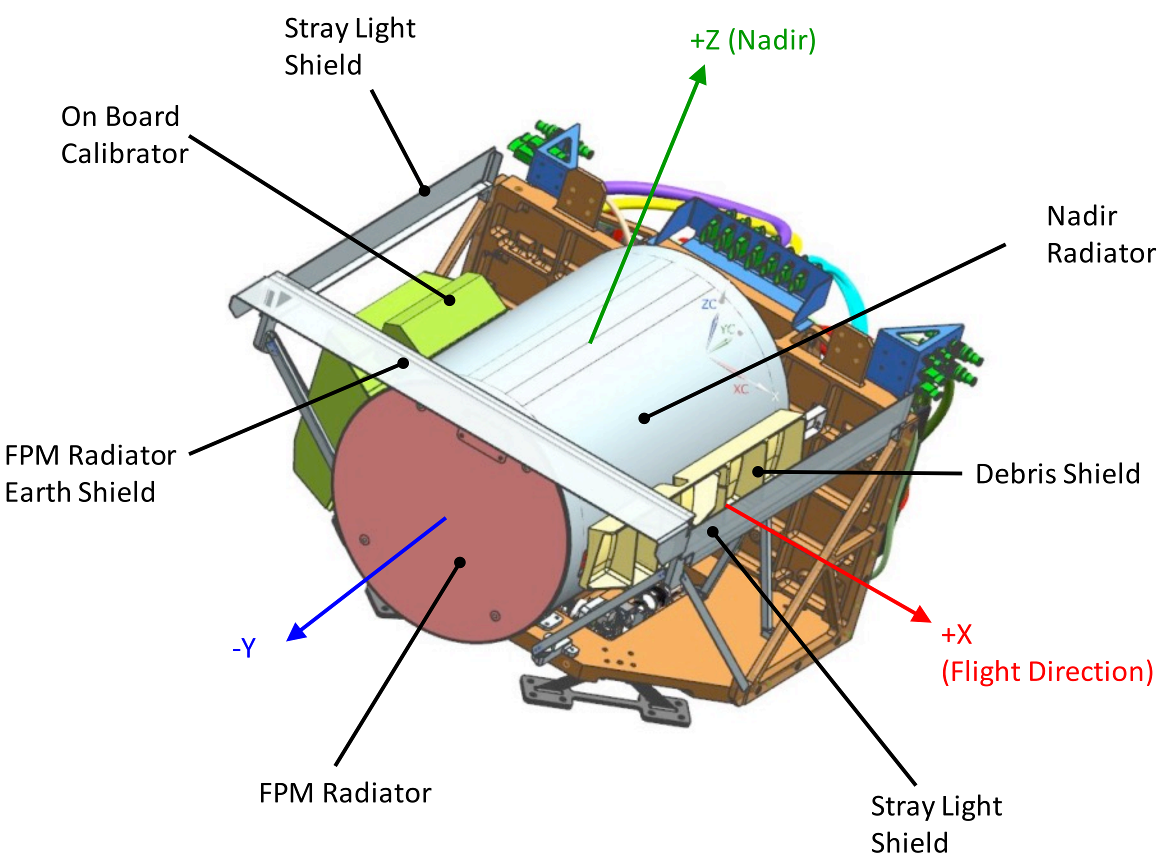


Background (3 of 3)

- Scan rotations of ± 58°, give a ± 60° along track field of regard
- Pan rotations of ± 30°, give a ± 45° across track field of regard
- Spectral bands of interest span the 367 nm to 2126 nm range
- Detectors ≤ 225K to meet performance requirements

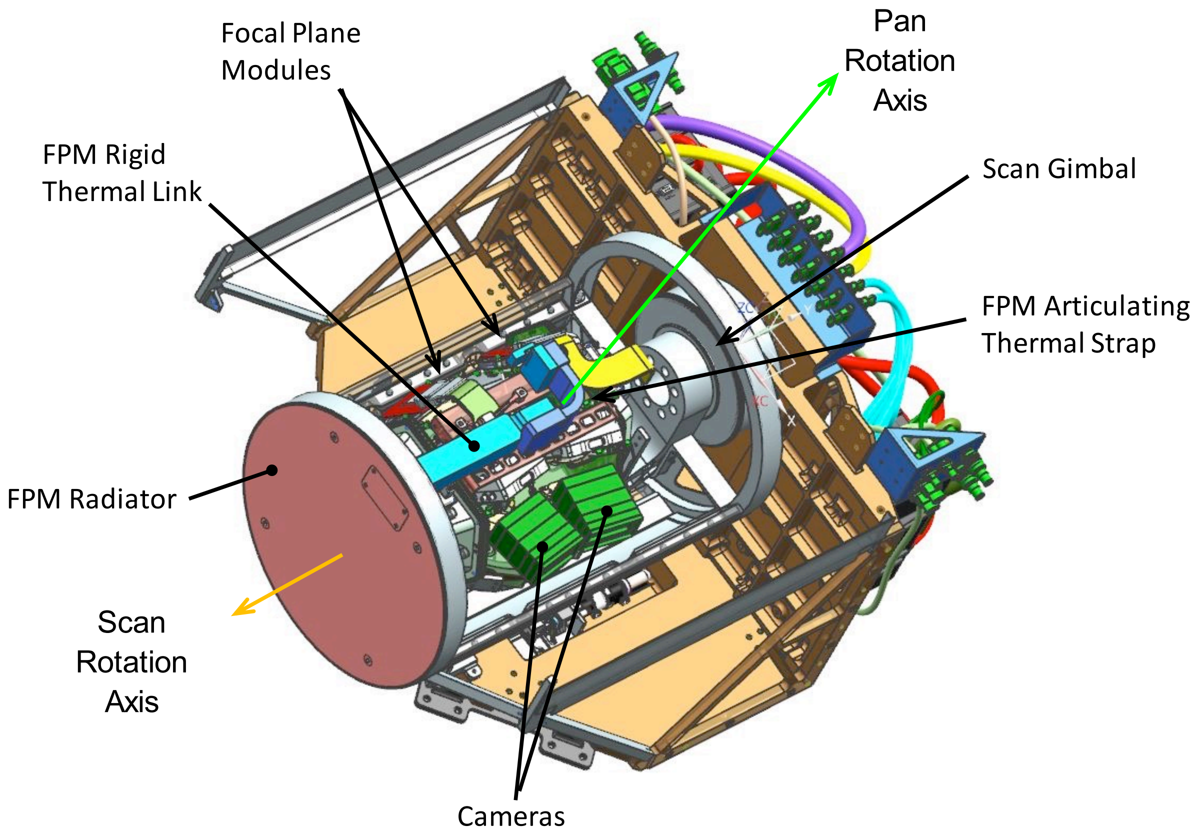
- The paper provides an overview of:
  - The MAIA thermal control system baseline
  - Articulating thermal strap risk reduction life testing
  - Hosted payload considerations

Instrument Description (1 of 4)



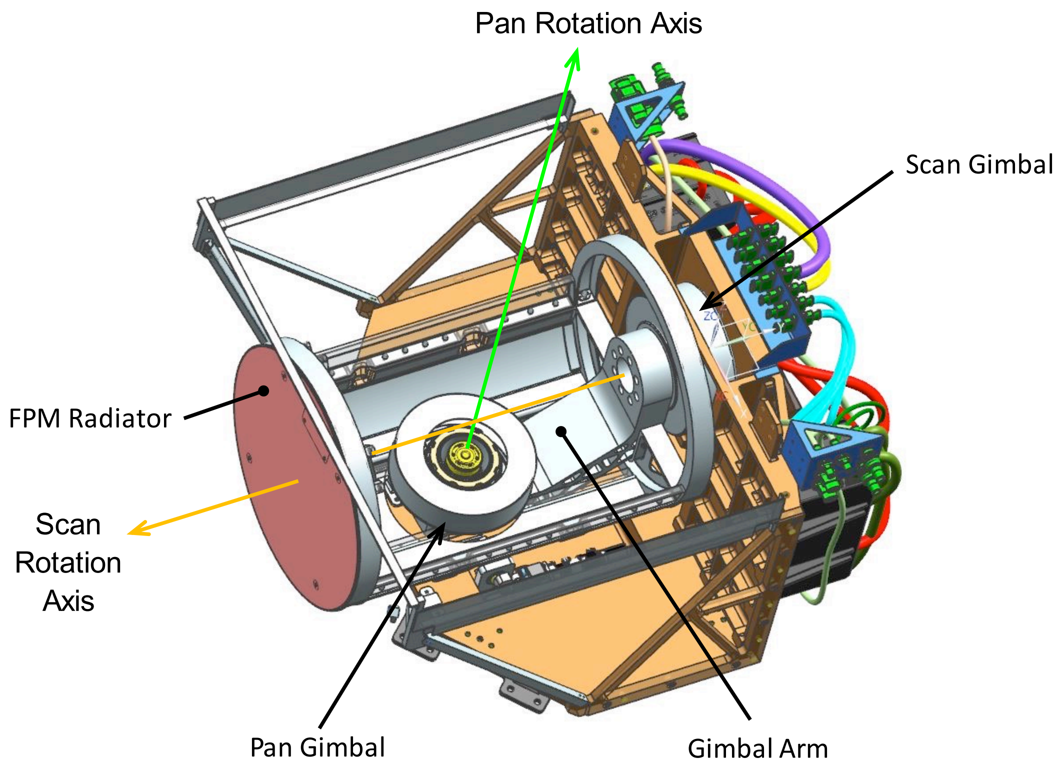
- Focal Plane Module (FPM) radiator: anti-sun side of orbit
- Nadir radiator: near constant projected area in nadir direction

Instrument Description (2 of 4)



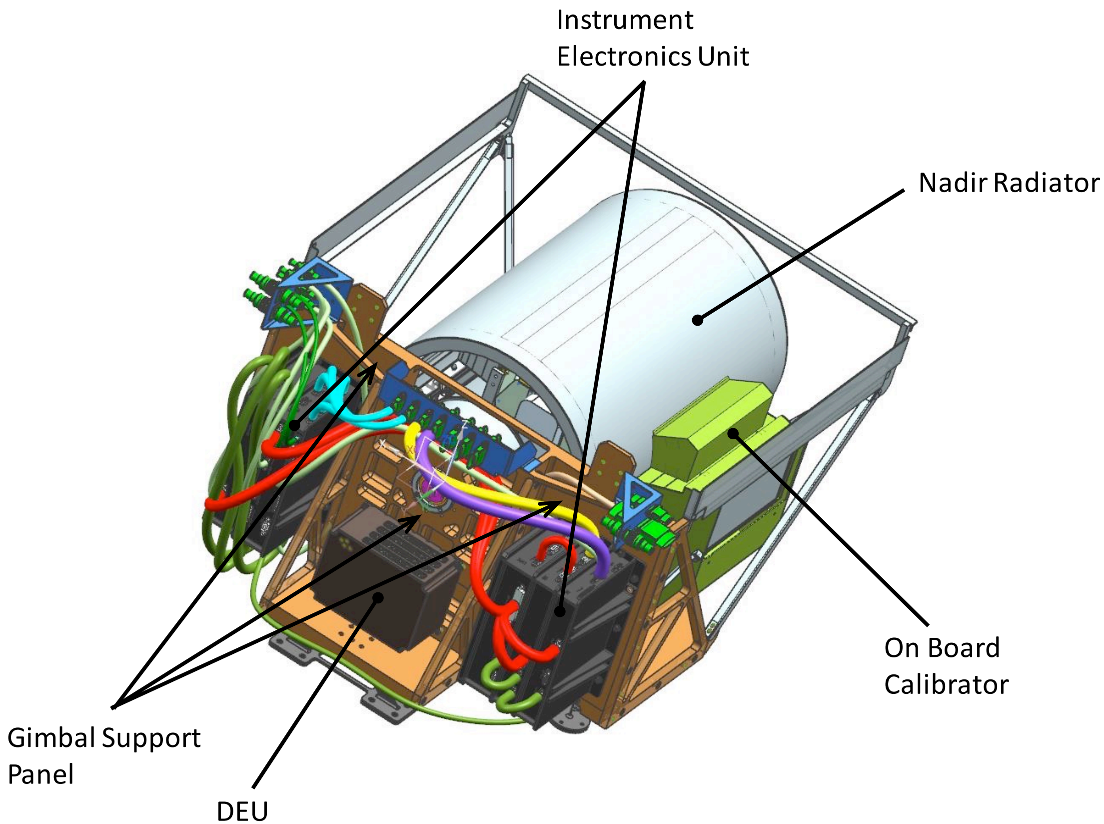
- Cameras / FPMs rotate about Pan axis inside Nadir Radiator
- Articulating thermal strap couples FPMs to FPM radiators across Pan rotation axis

Instrument Description (3 of 4)



- Gimbal Arm rotates with Scan Gimbal
- Pan Gimbal mounts to end of Gimbal Arm
- Both FPM radiator and Nadir radiator rotate about Scan Axis

Instrument Description (4 of 4)

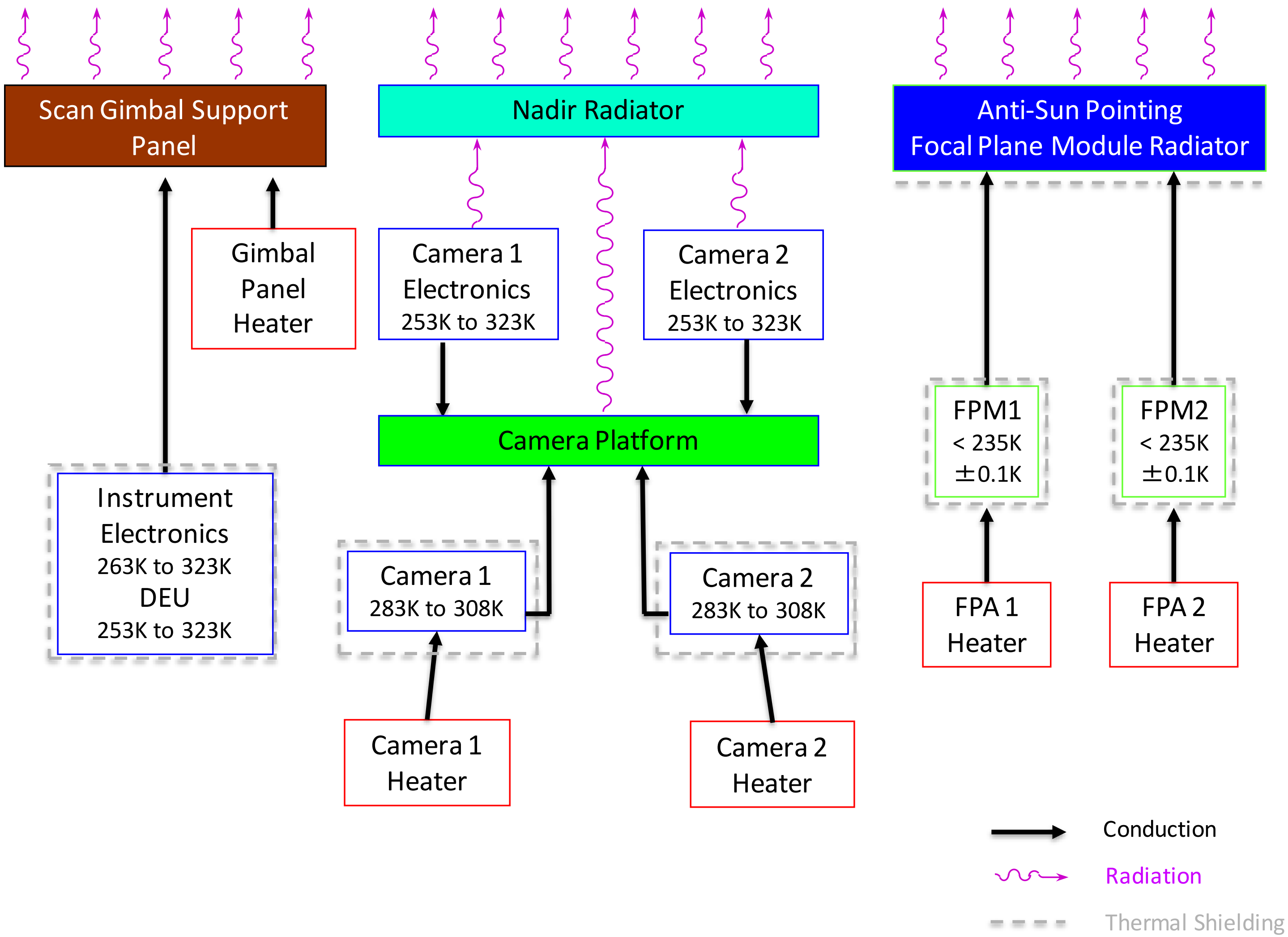


- Instrument Electronics and Drive Electronics Unit (DEU) use Gimbal Support Panel as radiating surface

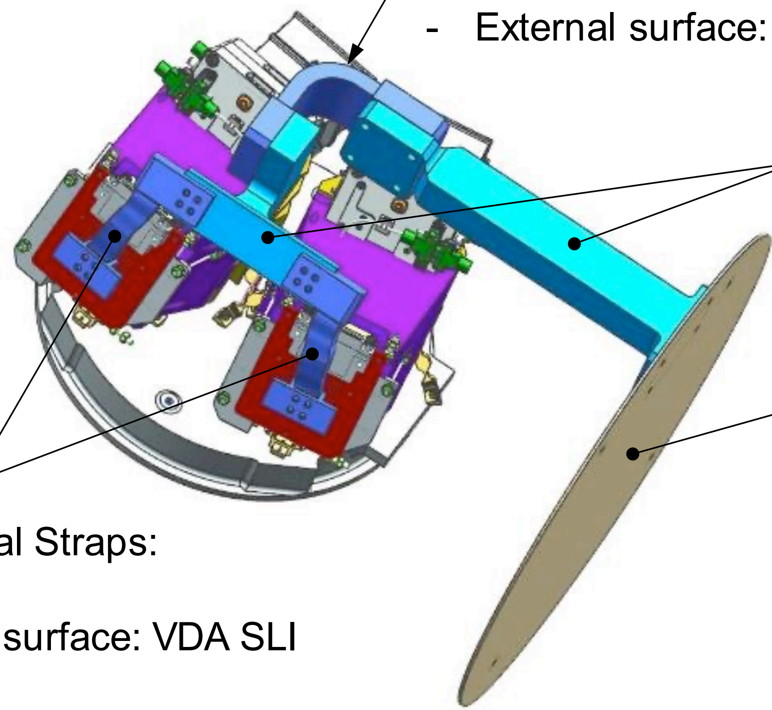
Thermal Control Requirements

- Notable thermal design requirements
  - FPM temperatures ≤ 225K
  - FPM stability ±0.1K
  - Camera temperatures 283K to 308K
  - Camera stability ±0.5K

Thermal Control Architecture

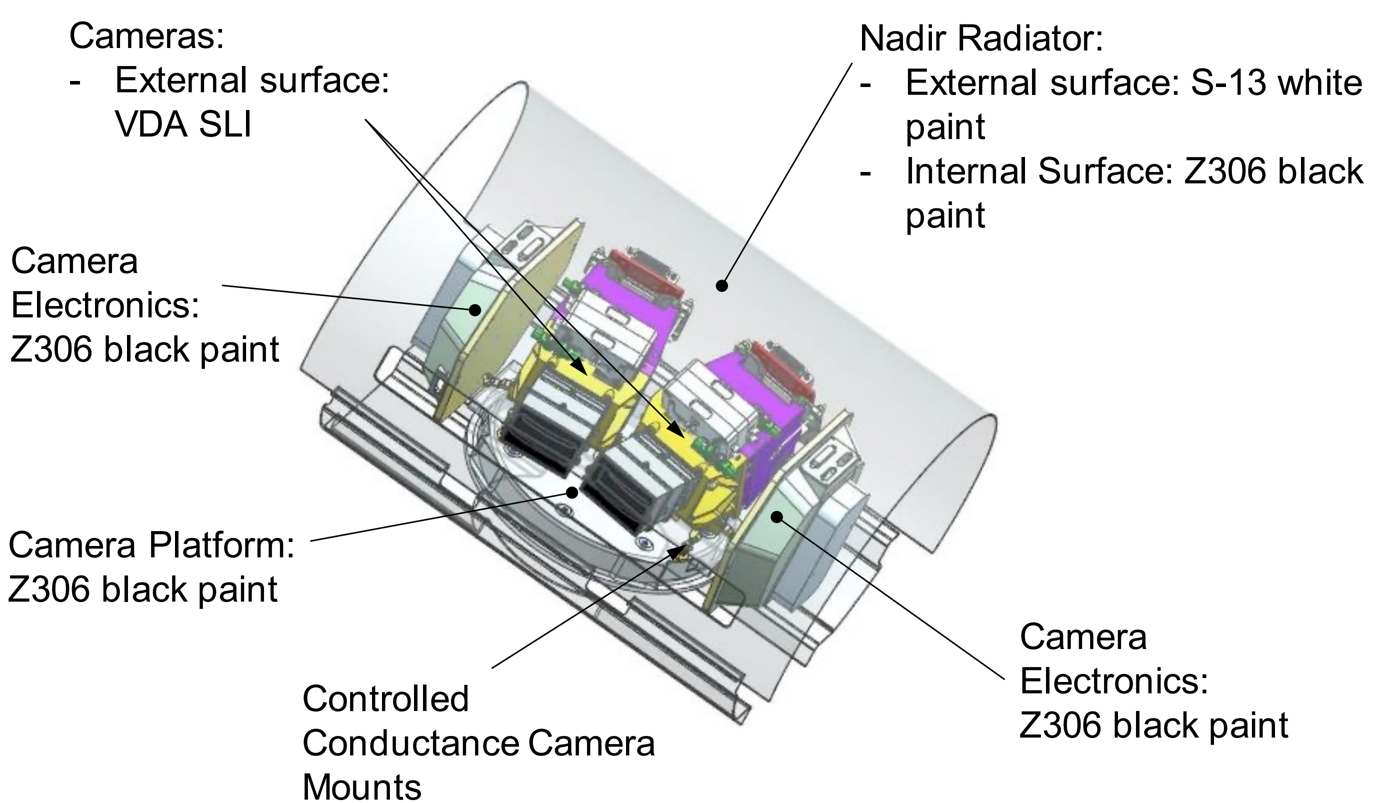


Focal Plane Module Temperature Control



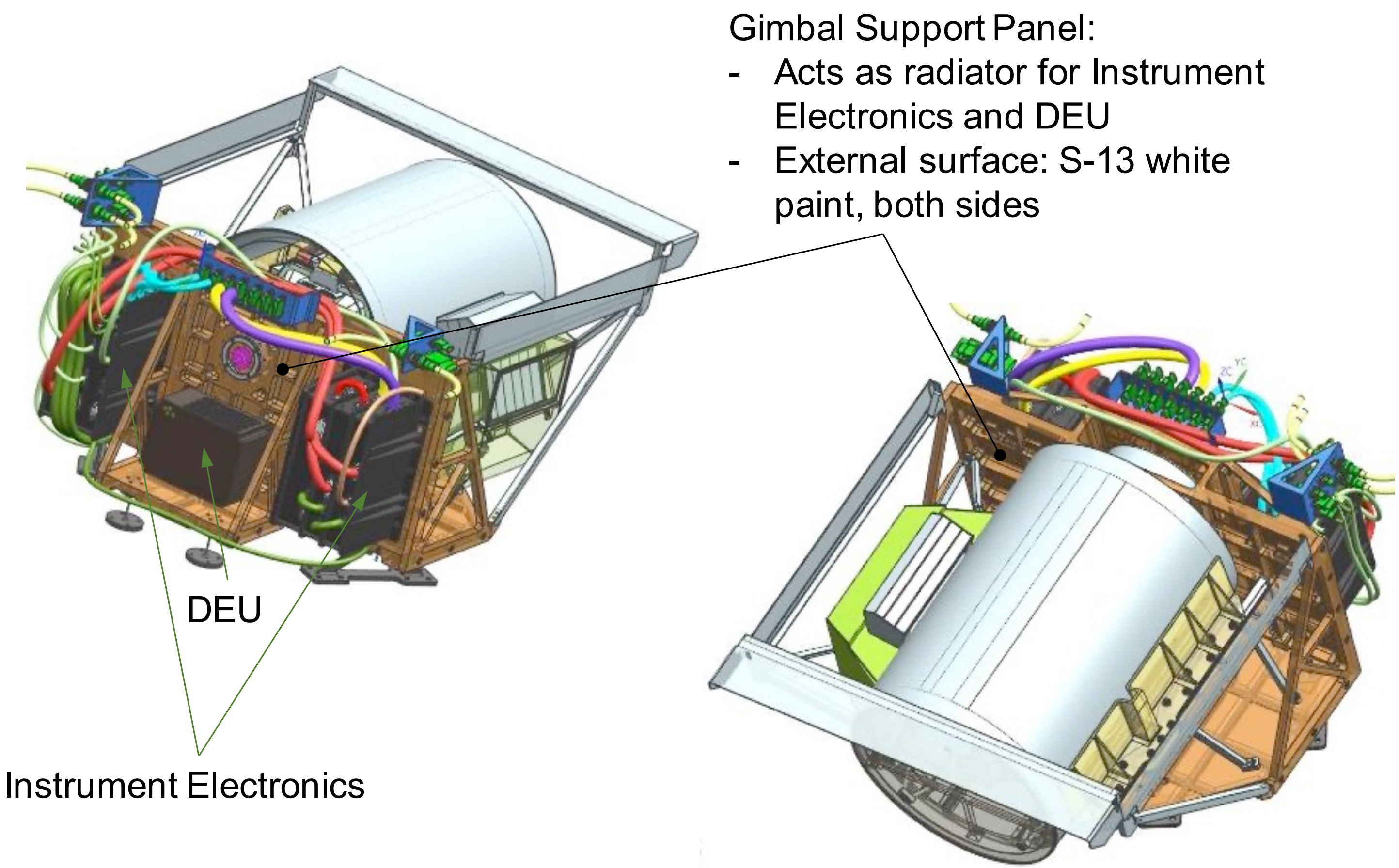
- Temperature Sensors and Heaters are mounted to FPM thermal strap end fittings

Camera Temperature Control



- Temperature Sensors and Heaters are mounted to the bodies of the camera assemblies

Electronics Temperature Control



- Temperature Sensors and Heaters are mounted to the Gimbal Support Panel

Unit Dissipations

Unit	Maximum Expected Dissipation (Per Unit, W)	Orbital Avg. Dissipation (Per Unit, W)
Camera Electronics	9.36	9.36
Camera (Modulator & Probe)	0.42	0.42
DEU	3.64	3.64
FPM Dissipation	0.295	0.295
Instrument Electronics	27.6	27.6
Pan Gimbal Actuator	21.8	3.43
Scan Gimbal Actuator	21.8	3.43

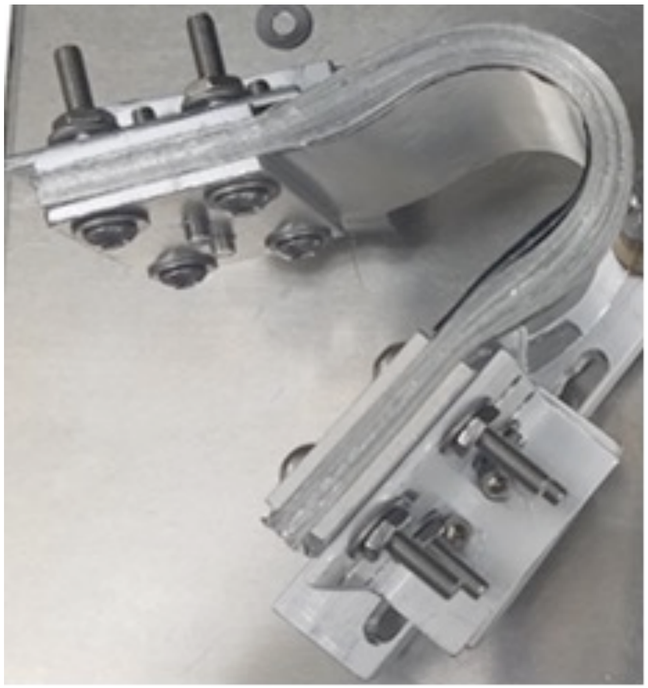
Articulating Thermal Strap Life Test

- During the MAIA mission, the articulating thermal strap is expected to undergo 32,000 cycles over its entire rotational range

- Prototype articulating thermal strap was tested to >260,000 cycles or >8X mission life

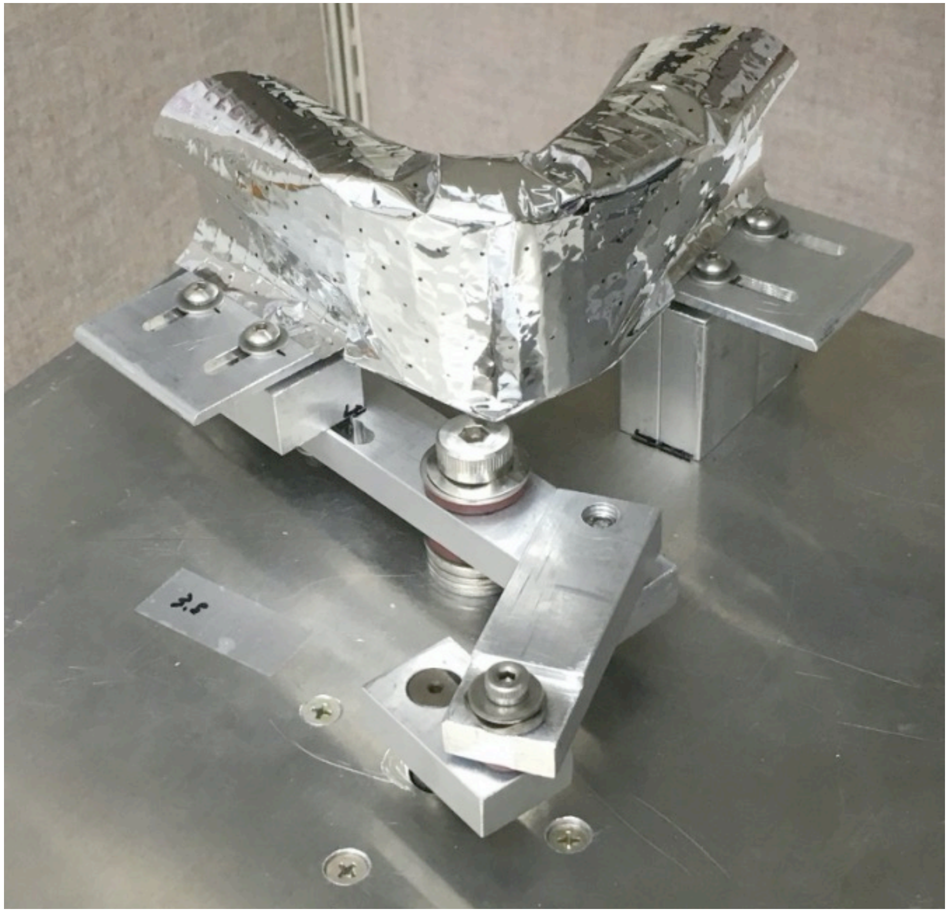
- Prototype articulating thermal strap blanket was tested to >130,000 cycles of >4X mission life

Prototype Articulating Thermal Strap



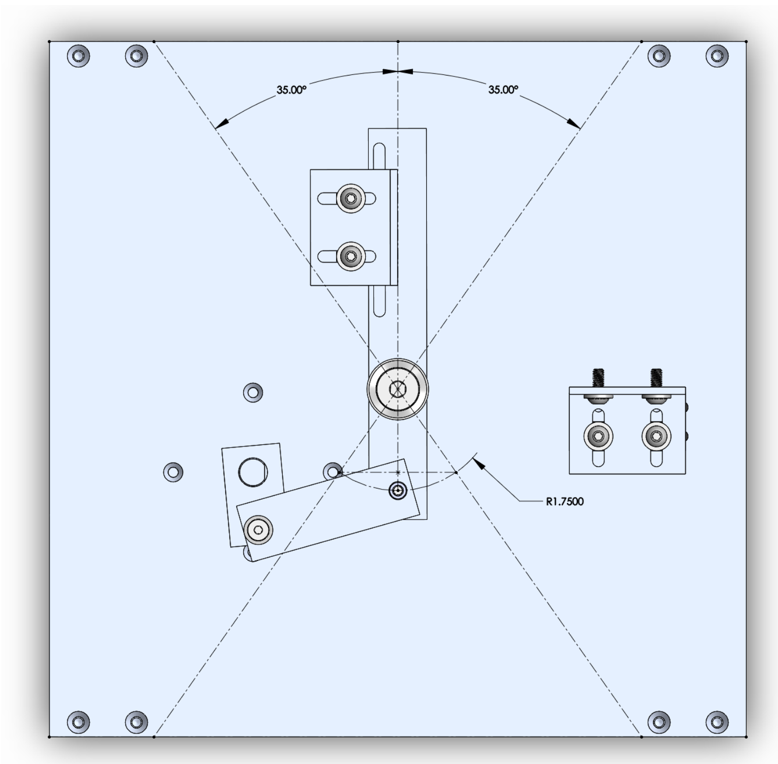
- 400 layers of alloy 1100 aluminum foil
- 20 cm long x 5 cm wide

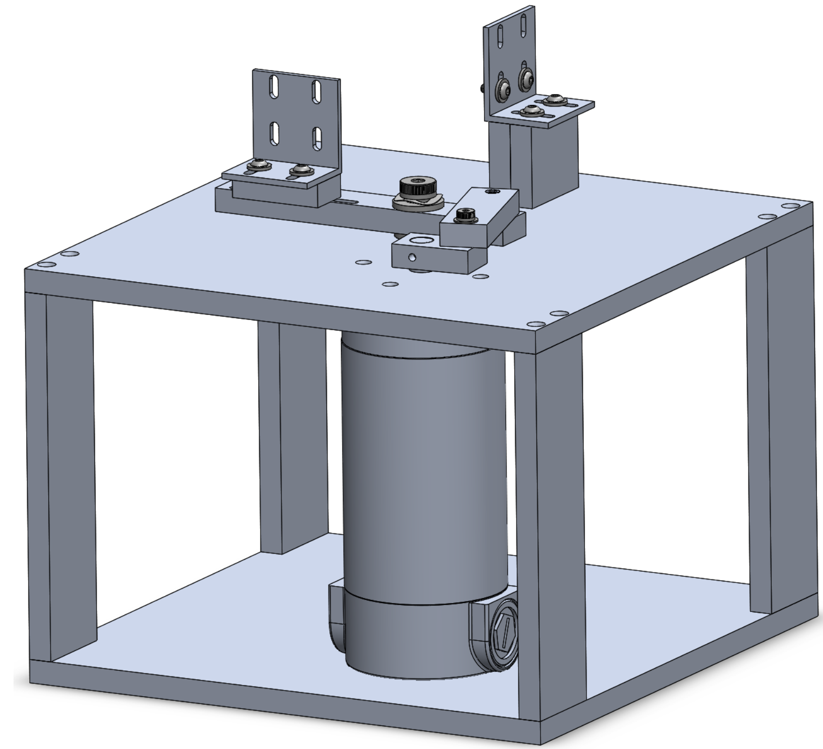
Articulating Thermal Strap Blanket



- Single layer of VDA coated Kapton

Articulating Thermal Strap Life Test Machine

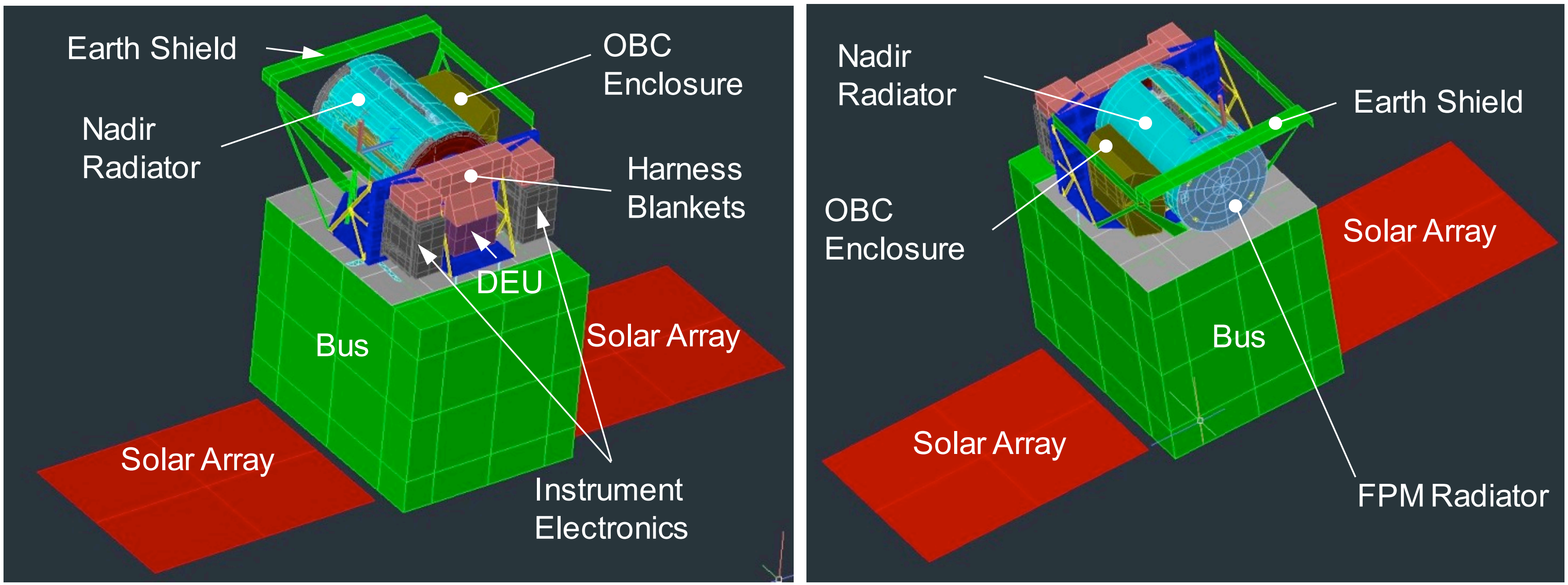




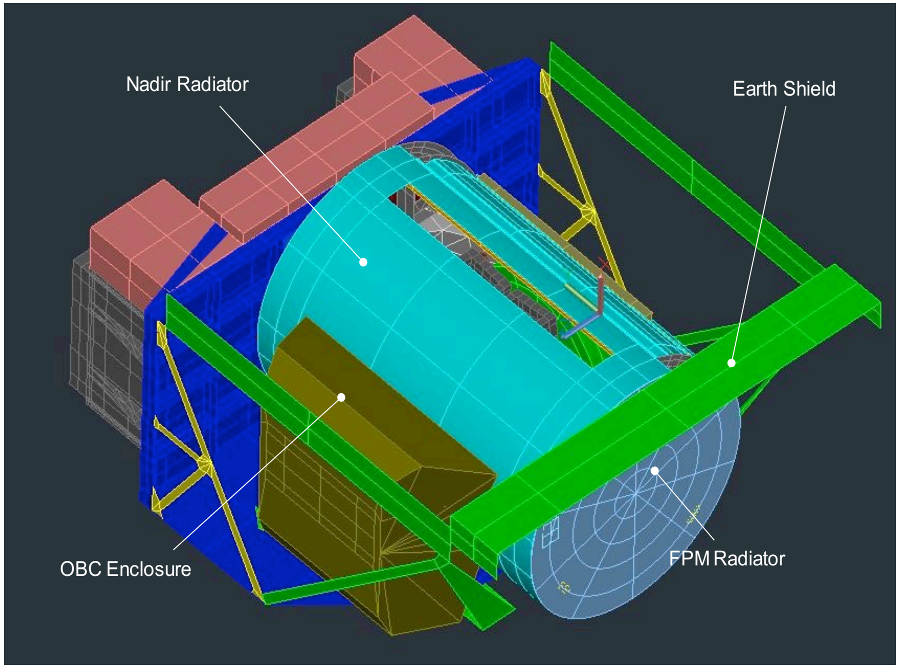
Articulating Thermal Strap Life Test Outcome

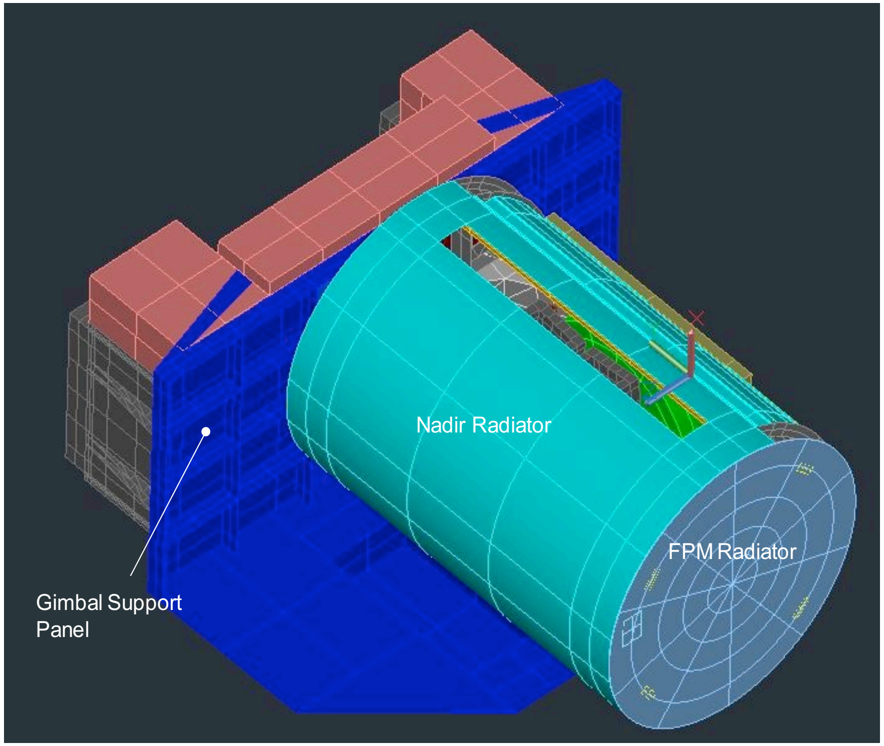
- Minor permanent creasing of the SLI blanket
- No visible particulate accumulation
- No visible damage to thermal strap

Thermal Model (1 of 3)

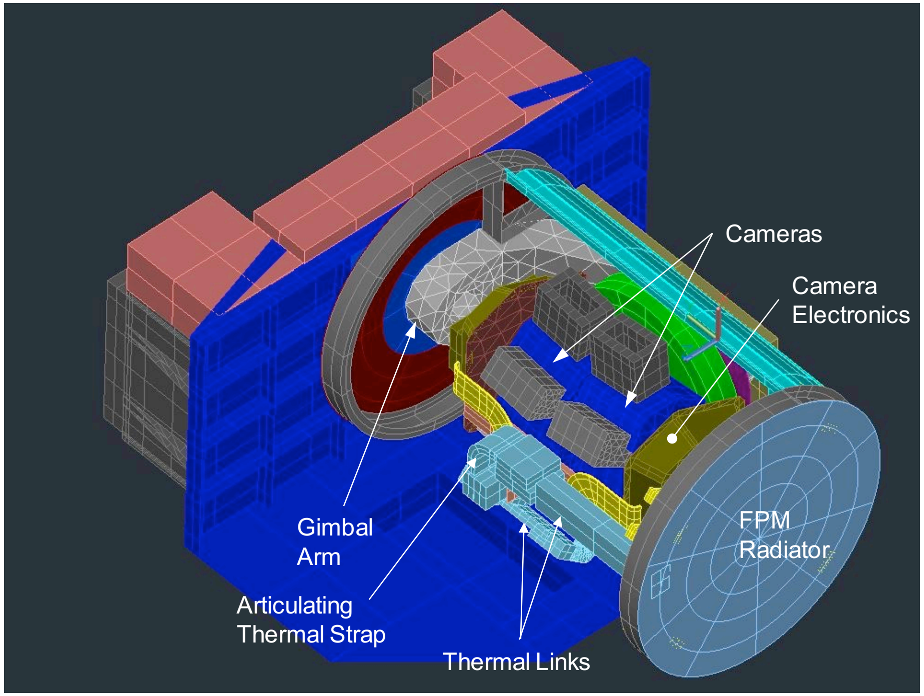


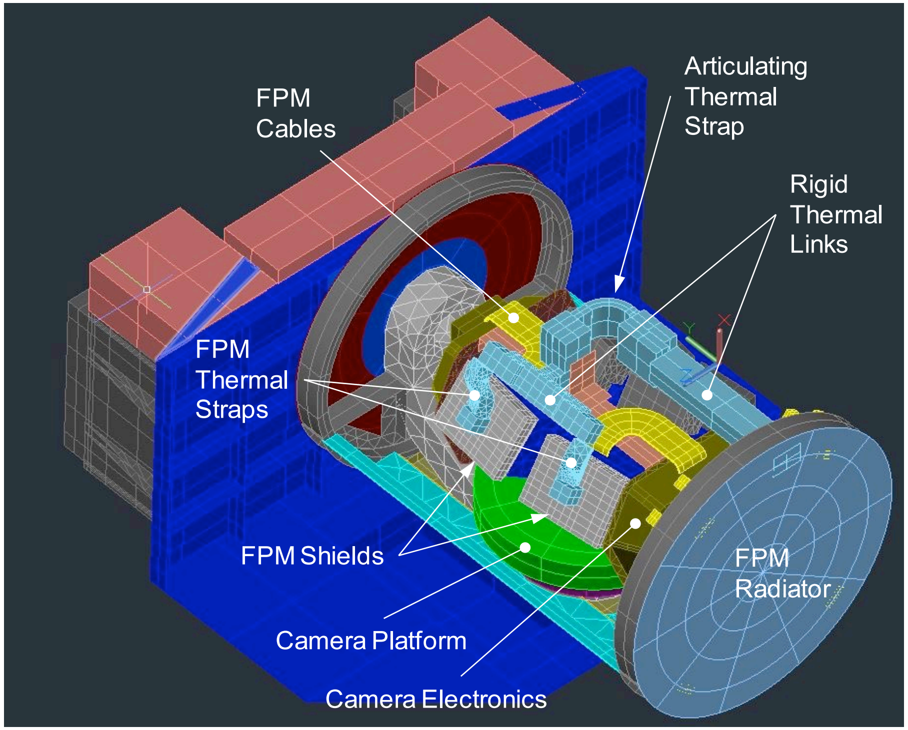
Thermal Models (2 of 3)





Thermal Models (3 of 3)





Notable Optical Property Assumptions

Material Description	Solar Absorptivity (α)		Hemispherical Infrared Emissivity (ε)	
	BOL	EOL	BOL	EOL
Fused Silica (Quartz)	0.015	0.025	0.9	0.9
Vapor Deposited Aluminum Coated Kapton, Aluminum Side	0.12	0.12	0.03	0.03
Vapor Deposited Aluminum Coated Kapton, Kapton Side	0.49	0.7	0.83	0.83
Z306 Black Paint	0.95	0.93	0.87	0.87
S-13 White Paint	0.22	0.39	0.88	0.88

Bounding Operational Case Assumptions

Case No	Description	Orbit	Beta (°)	Alt. (km)	Pointing	Solar Const. (W/m2)	Albedo Fraction	Earth IR (W/m2)	Optical Property Condition
C1	Bounding Cold Operational	Sun Sync	1	850	FPM Radiator Anti-Sun	1322	0.24	218	BOL
H1	Bounding Hot Operationall	Sun Sync	55	600	FPM Radiator Anti-Sun	1414	0.35	244	EOL

Selected Analysis Results

Focal Plane Module

Case No	Description	FPM Radiator		+Y FPM			-Y FPM			Operational Temperature Limits (K)	
		Orbit Min Node (K)	Orbit Max Node (K)	Orbit Min Node (K)	Orbit Max Node (K)	Max Nodal Variation (K)	Orbit Min Node (K)	Orbit Max Node (K)	Max Nodal Variation (K)	Min (K)	Max (K)
C1	Bounding Cold Operational	190.6	192.9	200.72	200.82	0.05	200.72	201.08	0.04	195	300
H1	Bounding Hot Operational	210.7	213.5	225.70	225.82	0.05	225.70	226.17	0.07		

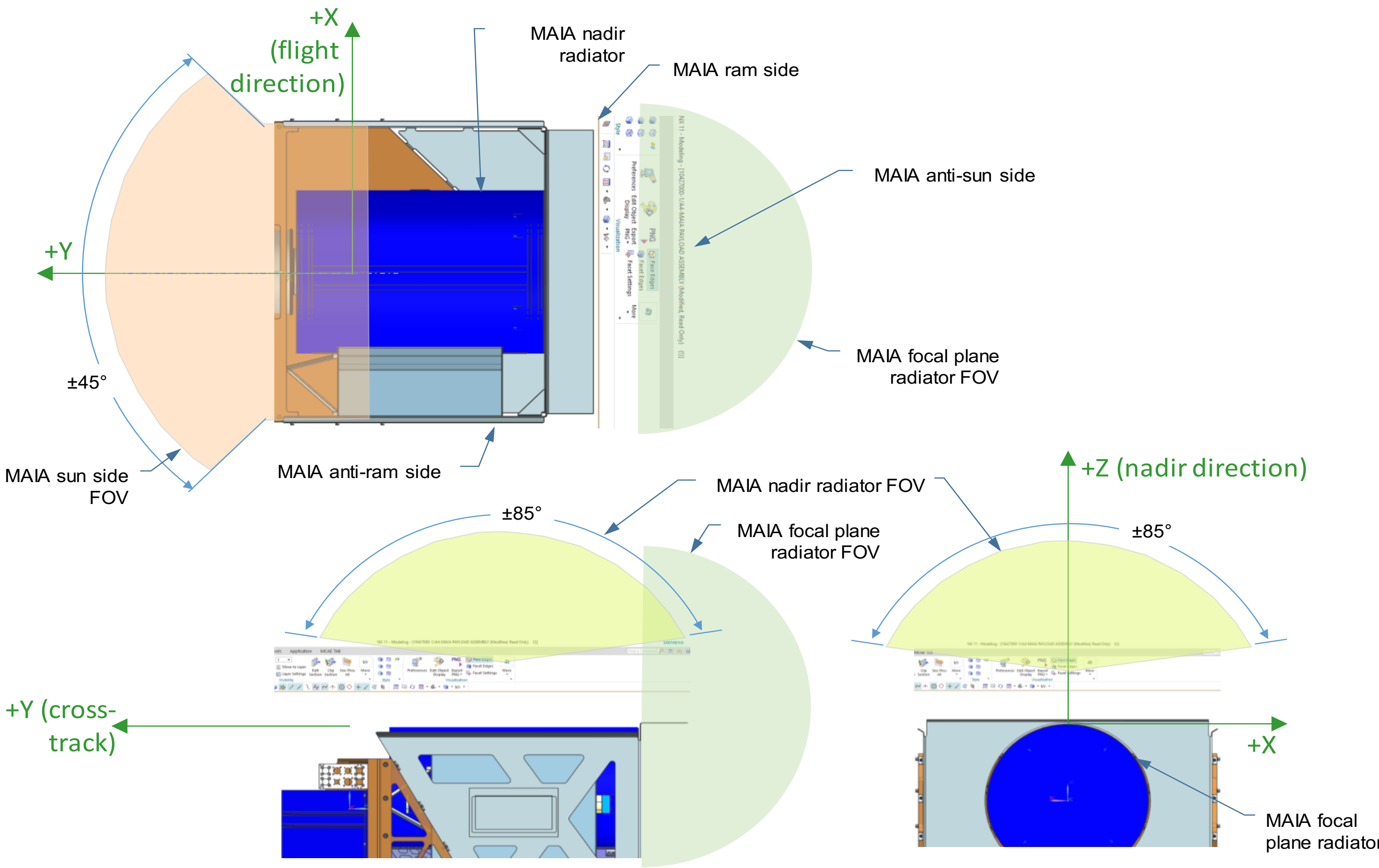
Camera

Case No	Description	Nadir Radiator		+Y Camera			-Y Camera			Operational Temperature Limits (K)	
		Orbit Min (K)	Orbit Max (K)	Orbit Min Node (K)	Orbit Max Node (K)	Max Nodal Variation (K)	Orbit Min Node (K)	Orbit Max Node (K)	Max Nodal Variation (K)	Min (K)	Max (K)
C1	Bounding Cold Operational	242.6	257.7	282.44	282.83	0.26	282.46	282.83	0.24	283	308
H1	Bounding Hot Operational	283.4	297.6	307.71	308.12	0.20	307.69	308.06	0.19	283	308

Hosted Payload Considerations

- The MAIA project will have no knowledge of the spacecraft bus configuration, or adjacent payloads until after the project's Critical Design Review
- MAIA host interface requirement documentation includes a number of constraints including:
    - Field-of-view (FOV) stay-out zones
    - Restrictions on the amount of infrared and solar spectrum radiation incident upon the MAIA instrument which is emitted from, or reflected by, adjacent payload and spacecraft bus surfaces
    - Allowable range of heat flow at the MAIA instrument to bus interface

FOV Stay-Out Zones



Summary / Conclusion

- Risk reduction testing indicates that the approach of using a rotationally articulating thermal strap to transfer heat across the instrument's rotating pan axis is consistent with mission life requirements

- Thermal modeling indicates that the MAIA thermal control system design can maintain the MAIA instrument within operational temperature limits and stability requirements

Acknowledgements

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[1] Jet Propulsion Laboratory, California Institute of Technology